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# ARMORED MEDICAL RESEARCH LABORATORY

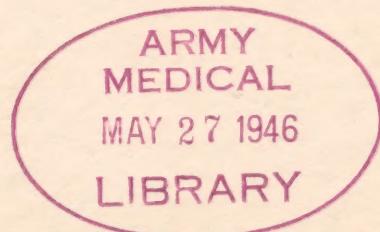
FORT KNOX, KENTUCKY

INDEXED

PROJECT NO. 2 - HIGH TEMPERATURES IN TANKS

Final Report On

Sub-Project No. 2-28, Test of Individual Crew Conditioning System



Project No. 2-28

INFORMATION COPY

April 27, 1943



ARMORED FORCE MEDICAL RESEARCH LABORATORY  
Fort Knox, Kentucky

Project No. 2-28  
727-2 GNOML

April 27, 1943

1. PROJECT: No. 2 - High Temperatures in Tanks. Final Report on:  
Sub-Project No. 2-28, Test of Individual Crew Conditioning System.

a. Authority - Letter Headquarters Army Ground Forces, Army War College, Washington, D. C., 470.81/157 GNRQT/6/ 34278 (3-14-43) and first indorsement Armored Force Headquarters, Fort Knox, Kentucky, 421.52 (3-14-43) GNOHD.

b. Purpose - To test the physiological reactions of soldiers wearing the subject suit under a variety of climatic conditions.

2. DISCUSSION:

a. Men were conditioned by marching 12.5 miles per day and trained to walk with and without the jackets on a motor-driven treadmill at intervals for at least a week before being exposed to the heat. They were then given measured amounts of similar work in the hot room under a variety of climatic conditions and their reactions studied with and without the air-conditioned jackets. Details of the procedure and description of the suit are given in the Appendix.

3. CONCLUSIONS:

a. The air-cooled suit cools men satisfactorily whether working under extreme conditions of dry heat as found in the desert or in moist jungle heat.

b. For all practical purposes under the conditions tested the suit is as effective when supplied with air at a temperature of  $80^{\circ}\text{F}$  ( $26.5^{\circ}\text{C}$ ) as it is with air at a temperature of  $70^{\circ}\text{F}$  ( $20^{\circ}\text{C}$ ). Par. c, Appendix

c. The addition of a plastic visor to the face orifice of the suit does not contribute to the effective cooling power.

d. The air-cooled suit is not a substitute for acclimatization. Even with the suit, unacclimatized men do not do well at extremely high temperatures.



e. All factors which tend to diminish a man's ability to work in the heat (loss of acclimatization, fatigue, illness, alcohol, age, etc.) are operative without regard to the cooled suit.

4. RECOMMENDATIONS: That the suit be considered adequate for individual cooling under all conditions likely to be met with Armored Force personnel. (The question of the actual need for the suit is discussed in the Appendix).

Prepared by:

William F. Ashe, Major, M.C.  
William B. Bean, Captain, M.C.

APPROVED

Willard Machle

WILLARD MACHEL

Colonel, Medical Corps  
Commanding

2 Incl.

- # 1 - Letter of Authority
- # 2 - Appendix with drawings
- 1, 2 and Charts 1, 2, 3,
- 4, 5, 6, 7



HEADQUARTERS  
ARMY GROUND FORCES  
Army War College  
Washington, D. C.

470.81/157 GNRQT/6/34278  
(3-14-43)

March 14, 1943

SUBJECT: Air Conditioning of Helmet or Jacket for Individual Tank Crew Members.

TO : Chief of the Armored Force, Fort Knox, Kentucky.

It is desired that the Armored Force Medical Research Laboratory conduct tests on individual crew type air conditioned helmets and jackets, manufactured by Carrier Corporation, in general accordance with the information contained in the attached test data sheet, No. Armored Force Medical - 136.

By command of LT. GEN. McNAIR:

i Incl.  
Test data sheet  
No. AFM - 136 (in dup)

/s/ J. R. Dryden  
/t/ J. R. DRYDEN  
Lt. Col., A. G. D.,  
Asst. Ground Adj. Gen.

Ind. #1



421.52 (3-14-43) GNOHD

1st Ind.

HEADQUARTERS ARMORED FORCE, Fort Knox, Kentucky, March 17, 1943.

To: Commanding Officer, Armored Force Medical Research Laboratory,  
Fort Knox, Kentucky.

For compliance.

By command of Lieutenant General DEVERS:

1 Incl: n/c.

/s/ C. M. Wells  
/t/ C. M. WELLS  
Lieut. Colonel, A.G.D.,  
Assistant Adjutant General

1. Men were conditioned by day and night tests for at least a week before being tested. The tests consisted of 100% cotton shirts and breeches. The men were exposed to temperatures ranging from 20° F. to 100° F. with a mean temperature of 50° F. The air was supplied to the men at the rate of 20 cubic feet per minute.

a. Men were studied under four specific climatic conditions:

(1) Severe Desert Heat. Dry bulb temp. 100°  
Rel. Hum. 30%

Men were tested in both the acclimated and unacclimated states.

(2) Extreme Desert Heat. Dry bulb temp. 100°  
Rel. Hum. 30%

Men who previously acclimatized to 100° F. heat were tested. Unacclimatized men cannot work at this temperature without special protection.

(3) Jungle Heat. Dry bulb temp. 80°  
Rel. Hum. 70%

Men were tested in both the acclimated and unacclimated states.

(4) Extreme Night Heat. Dry bulb temp. 100°  
Rel. Hum. 30%

Men were tested in the acclimated. Men tested 100% cotton shirts, woolen liner, all-wool undershirt.

Incl. #1



## APPENDIX

### 1. PROCEDURE:

a. The air-conditioned jacket supplied for test, developed by the Carrier Corporation, consists of a slip-over jacket of semi-permeable cloth with hood attached. It is made large and is provided with shoulder straps permitting the jacket to balloon over the shoulders as air passes through. The hood may be snapped on to the standard crash helmet. Cooled air is supplied to the jacket through a flexible fiber hose at the rate of 25 cubic feet per minute.

b. All men were conditioned by daily 12-1/2 mile marches with 20 pound pack for at least a week before being brought into the hot room. The work in the hot room consisted of 1 hour periods of marching without pack at controlled rates on the treadmill. Each man was tested on the treadmill at 75°F and a relative humidity of approximately 30 percent before being exposed to the heat. Each man was tested with and without the jacket so that he acted as his own control under a variety of climatic conditions and at two different work levels. In addition four men were tested with the air hose fastened by the belt under the shirt, cotton, instead of the jacket.

c. Men were studied under four specific climatic conditions:

(1) Severe Desert Heat.              Dry Bulb Temp. 120°F  
    Rel. Hum. Temp. 20%

Men were tested in both the acclimatized and unacclimatized state.

(2) Extreme Desert Heat.              Dry Bulb 135 - 138°F  
    Rel. Hum. 11 - 15%

Only men previously acclimatized to 120°F heat were tested. Unacclimatized men cannot work at this temperature without special protection.

(3) Jungle Heat.                      Dry Bulb Temp. 90°F  
    Rel. Hum. 96%

Men were tested in both the acclimatized and unacclimatized state.

(4) Extreme Moist Heat.              Dry Bulb Temp. 110°F  
    Rel. Hum. 90%

Men were tested in the suits only. Man cannot live under these conditions without protection.



d. The work consisted of marching at 3.25 miles per hour, which is equivalent to the work of a tank driver while driving cross-country over moderately bad terrain. During the first test (Cond. 1) the men were also tested at 4 mph, a work level more severe than is required of a tank driver under the most severe driving conditions.

e. The face opening in the suit was enlarged as indicated in drawing No. 1, to facilitate vision. Men preferred to have the face exposed as in drawing No. 2 rather than as provided in the hood originally. In addition men wore trousers, cotton, G.I. shoes and light woolen socks. When not wearing the suit men wore the shirt, cotton, instead.

f. Rations consisted of regular mess supplied to the men in the hot room by the mess officer of their own company. Water containing 0.1 percent salt was supplied as desired. Data on pulse rate, rectal temperature and weight were obtained before and after each work period.

## 2. RESULTS:

a. Condition No. 1 (Temp. 120°F Rel. Hum. 20%). Unacclimatized men with the suit on do nearly as well as they did in the cool climate. Men without the suit became dangerously fatigued during a single hour walk, at 4 mph. Chart No. 1 shows quite clearly that with the suit, unacclimatized men were able to work with relative safety. Without it, their average temperature at the end of a single hour was 104°F (40°C) with an average pulse rate at 170. With the shirt, cotton, cooling was not as effective as with the jacket, but was appreciable.

Chart No. 2 shows the results on the same group of men working at the same rate after acclimatization to desert heat. The men wearing the suit did as well as when working in a cool climate. The men without the suit show slightly higher pulse rates and temperatures after work, but were in excellent condition. The suit is not essential to efficient work under these circumstances if the men are fully acclimatized and in excellent physical condition. They must, of course, be supplied with adequate salt and water and given adequate rest.

b. Condition No. 2 (Temp. 135 - 138°F Rel. Hum. 11 - 15%). Acclimatized men without special protection can do moderate work for a short time under this condition without danger of heat exhaustion. With the air-cooled suit, however, men can work much better under these circumstances and for a much longer time. See Chart No. 3.

c. Doing moderate work (3.25 mph) under condition 1 (120°F Rel. Hum. 20%). The suit is quite as efficient if the air delivered to it is 80°F (26.5°C) as it is if the air is kept at 70°F (20°C), the air in both cases having a relative humidity of 85% or higher. In neither instance do the men feel too cool. Under this climate and work regimen, however, no suit is needed for acclimatized men. See Chart No. 4.



d. Condition No. 3 (Temp. 90°F Rel. Hum. 96%). Unacclimatized men doing moderate work (3.25 mph) under these jungle conditions will collapse within an hour without the suit. When these same men wear the suit they can perform this work with safety but not with great efficiency. An air-cooled suit is not essential under these conditions if men are thoroughly acclimatized and are in good physical condition, but the suit increases their efficiency. See Chart No. 5. Again, the beneficial effects of the suit can be obtained with the suit air temperature at 80°F (26.5°C) as well as at 70°F (20°C).

e. Condition No. 4 (Temp. 110 Rel. Hum. 90%). Man cannot live under this condition without protection. A nude man at rest breathing cool air will develop a fever of 106°F in a few hours under this condition. (See Simpson and Kendall on Fever Therapy, Miami Valley Hospital, Dayton, Ohio). All men in this experiment worked at 3.25 mph. wearing the suit with the suit air temperature at 70°F (20°C). All four men selected for this trial were able to complete one work period. All were quite exhausted at the end. The cooling power of the suit is seen to be excellent when one compares these men with an unprotected man who rested for only 15 minutes in the hot room at the same time. See Chart 6. The suit was completely protective to a man at rest under these conditions.

### 3. DISCUSSION:

a. Conditions one and three were selected because they represent the maximum heat load (as far as temperature and humidity are concerned) to which men in the deserts or jungles of the world are subjected (As far as can be determined from available climatic data). Condition one (desert heat) is worse than that found in most deserts but excludes the very significant factor of radiant energy from the sun. Condition three (jungle heat) is very close to the limit at which mammals can live. It may be exceeded occasionally in some jungles for short periods, but is a fair representation of the severest condition known to exist. Under these conditions infantrymen clothed in standard summer combat uniforms (M-1942) can be trained to work efficiently without protection from heat by any cooling device. If, however, military occupation requires work within a closed vehicle, the climate within that vehicle may differ considerably from that of the outside. In a buttoned-up tank, for example, the temperature may be much higher than that outside. The same is true of ambulances, repair trucks, supply vehicles, etc.

b. The need for cooling is therefore determined by the climatic conditions encountered in specific tasks. This suit was designed with the thought that personnel cooling is needed in tanks. If tanks are to be fought buttoned-up and are to be protected against war gases, the need for personnel cooling becomes very real. In a buttoned-up gas-proof tank the quantity of air supplied to the crew will be much less than it now is. Furthermore it will, in all probability, be so small that the addition of sweat from the crew will raise the humidity of the hot air to intolerable



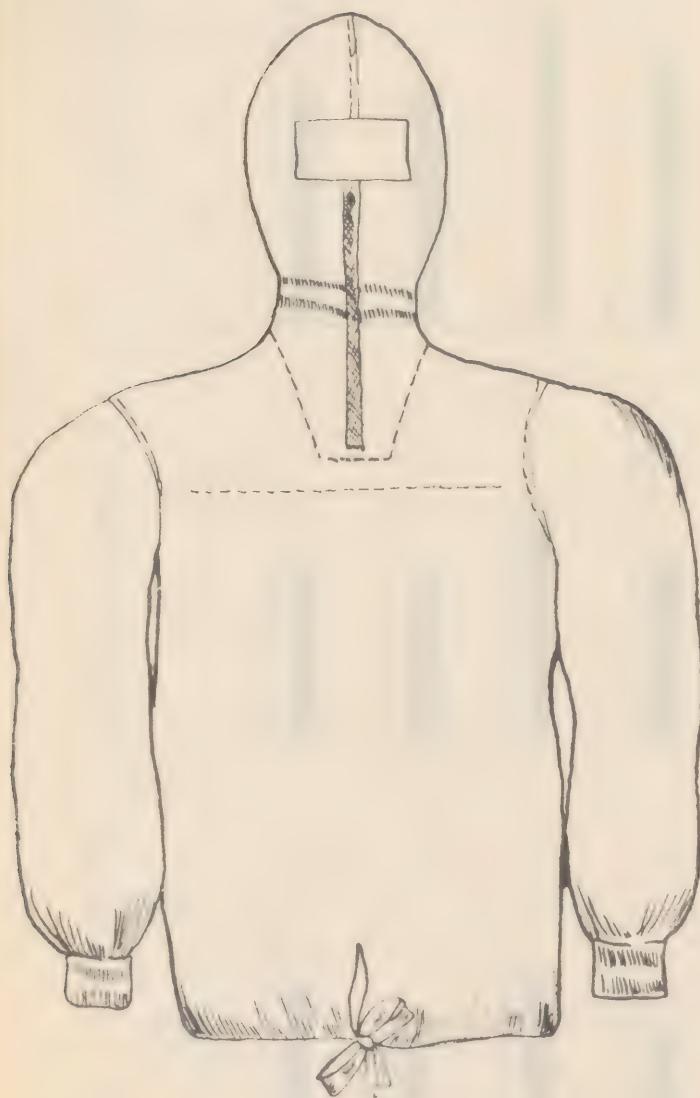
levels at the high temperatures encountered. Insulation of the tank walls, transmission housing and final drive will lower the heat load somewhat, but cannot keep tank air temperature below the level of outside air temperature. Such temperatures are tolerable if the relative humidity is low, but may become fatal if the relative humidity gets very high (See Chart 7). There is, therefore, the very real possibility that environmental states may develop in the tank at which men cannot live without protection. The actual facts are being determined at the present time and, together with the data of this report, should form the basis upon which the need for a personnel cooling system is determined.

As in all physiological experiments with human subjects, the factual data do not reveal the whole picture. The appearance and subjective reactions of the men as well as the data must be considered in evaluating results. For example, in Chart No. 5, the unacclimatized men with the suit seem to be nearly as good as the acclimatized men without. This is not the case. The former group were dizzy, light headed, weak, showed marked flushing of the face and were glad to lie down at the end of a work period. The acclimatized men looked and felt fine and were perfectly willing to continue their work. The conclusions here drawn are the opinions of trained observers after seeing the men during the performance of work and studying the factual data.

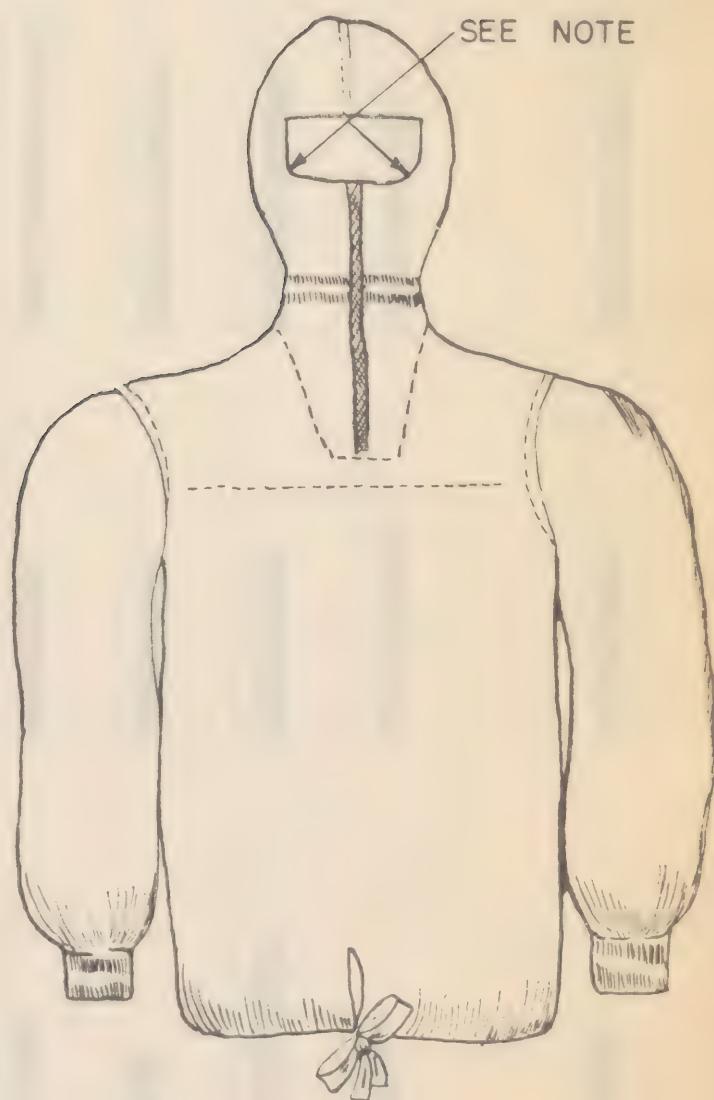


DRAWING I

SUIT AS RECEIVED



SUIT AS ALTERED



SEE NOTE

NOTE :

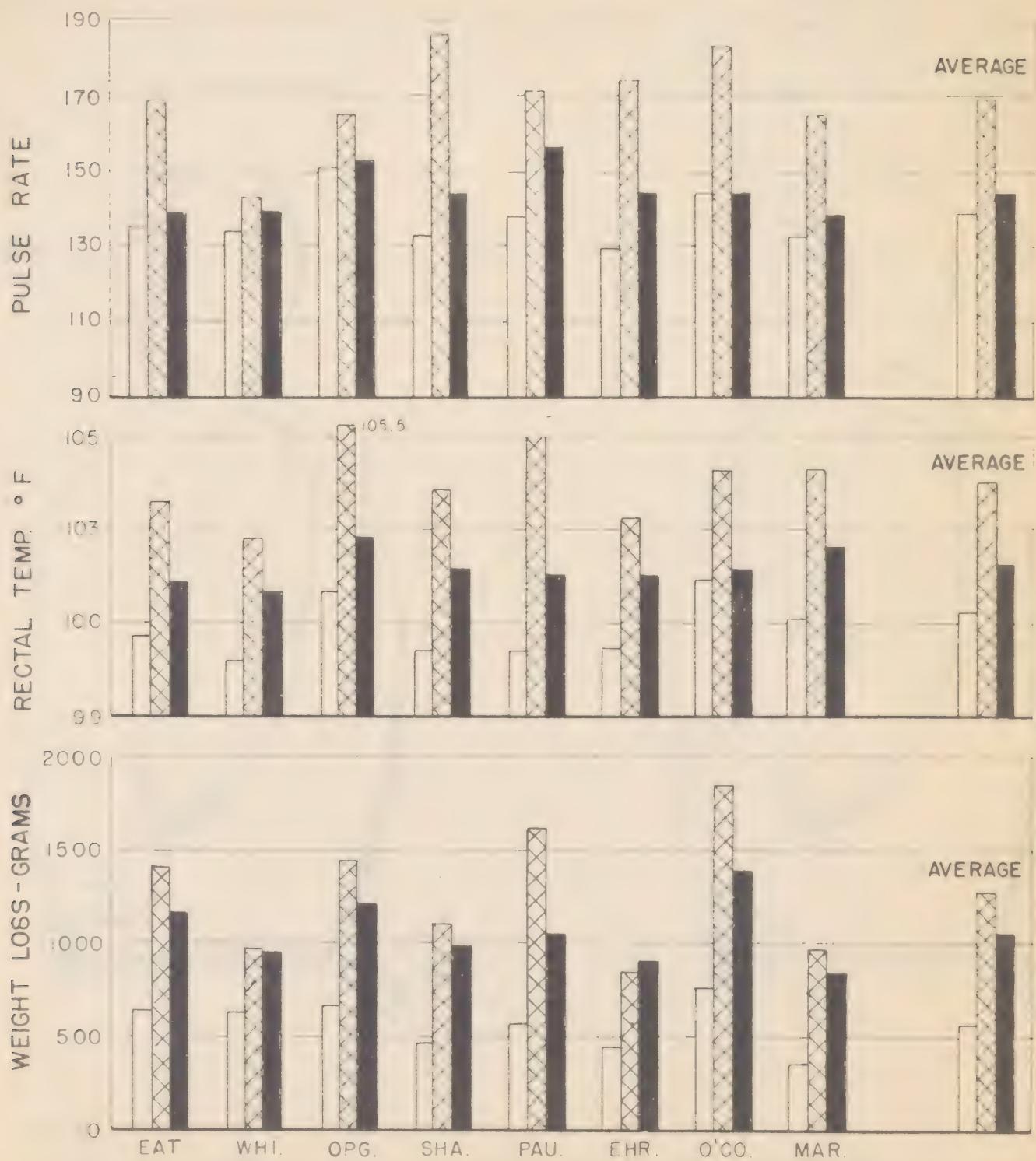
ALTERATION MADE BECAUSE OF NEED FOR INCREASED VISABILITY

DRAWING I



# CHART I

## EFFECT OF AIR-COOLING SUIT ON UNACCLIMATIZED MEN UNDER DESERT CONDITIONS



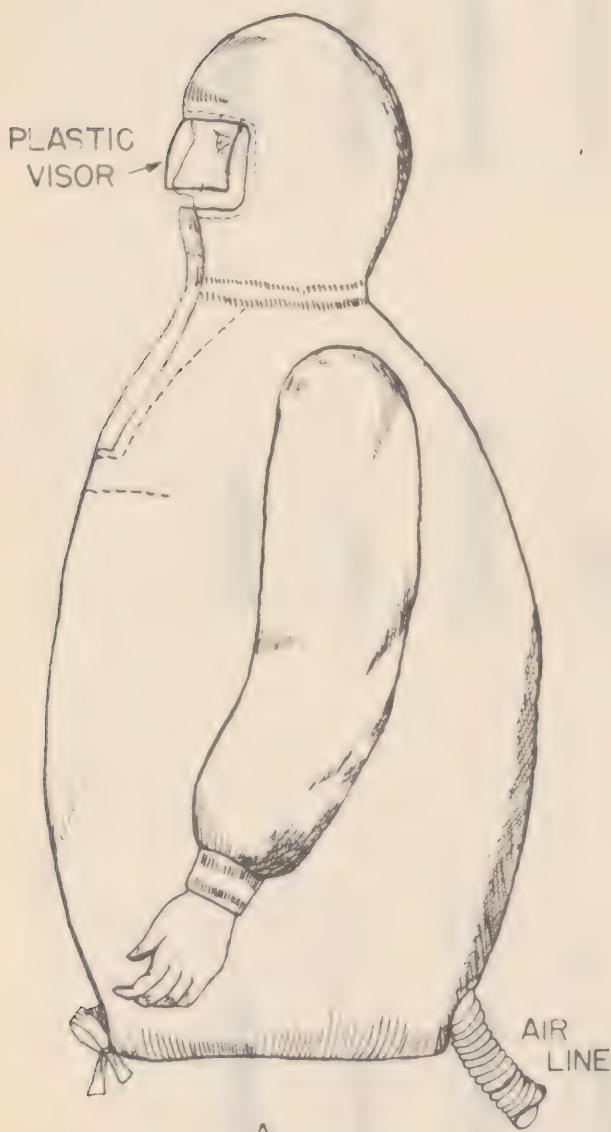
AIR TEMPERATURE 120 °F  
RELATIVE HUMIDITY 20%  
SUIT AIR TEMPERATURE 70 °F  
WORK RATE 4 MPH  
MEN - UNACCLIMATIZED

[Control Bar Pattern]	CONTROL
[No Suit Bar Pattern]	NO SUIT
[With Suit Bar Pattern]	WITH SUIT



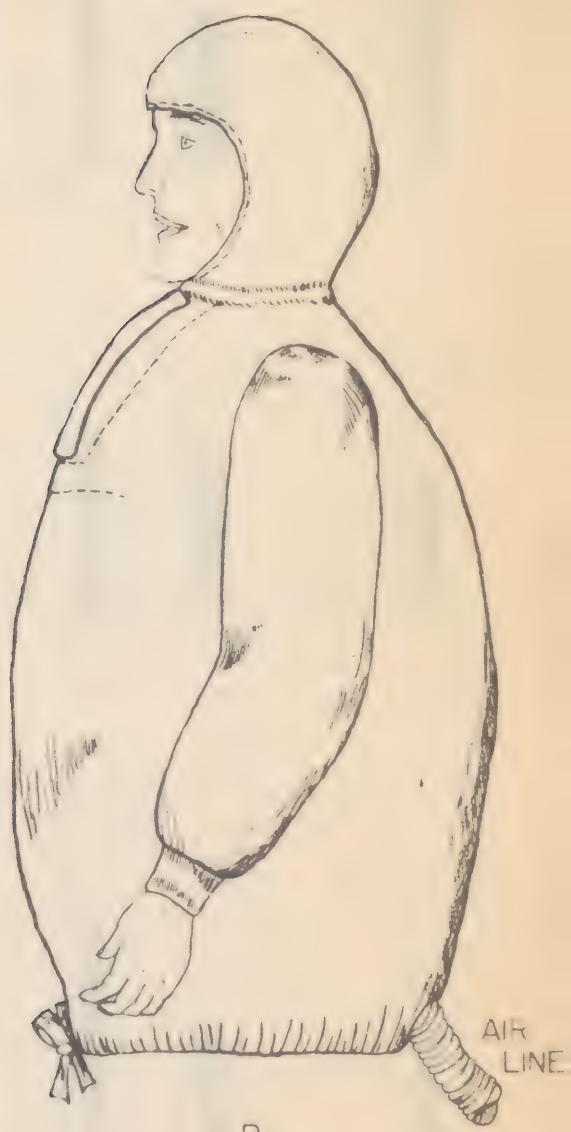
DRAWING 2

SUIT AS PRESCRIBED



A.

SUIT AS USUALLY WORN



B.

NOTE:

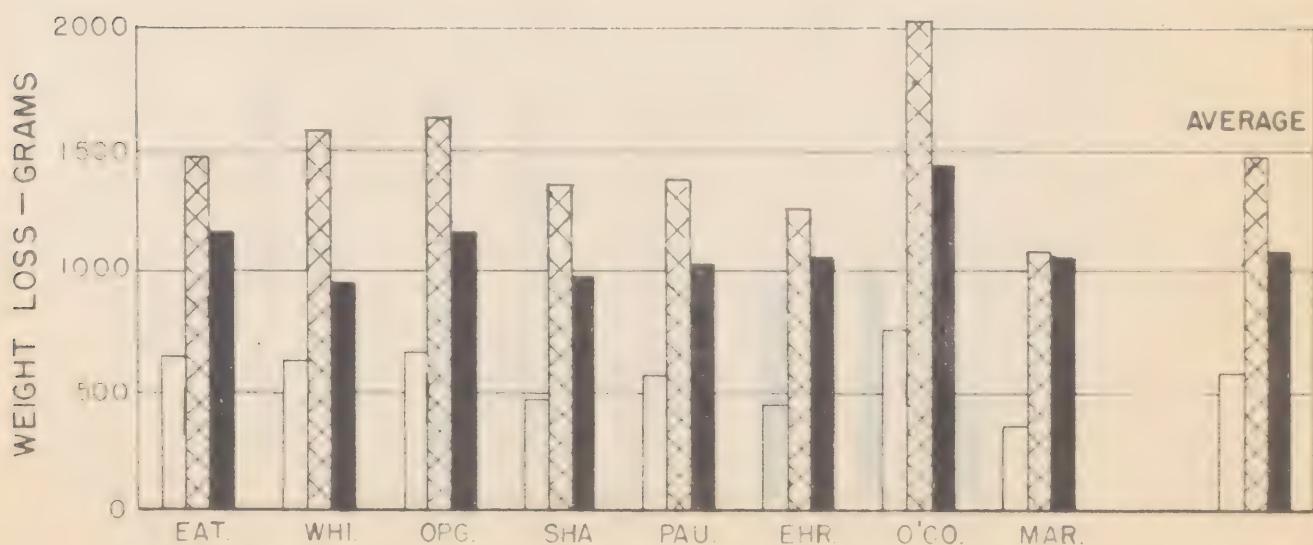
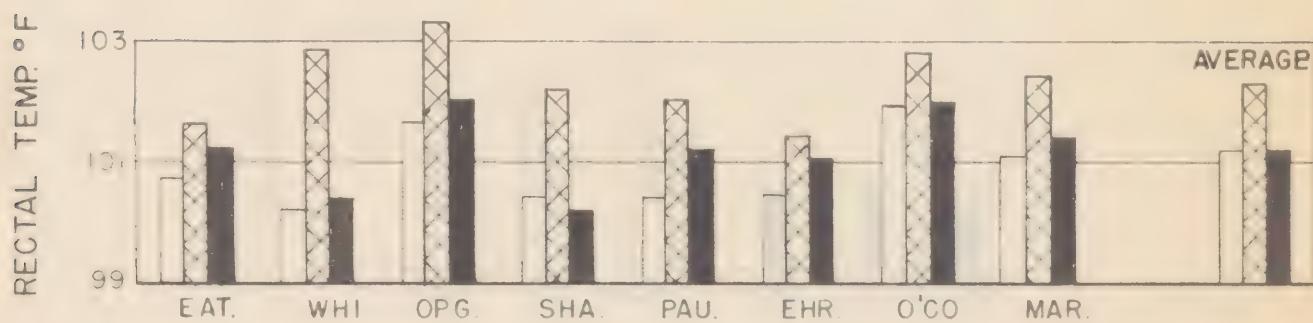
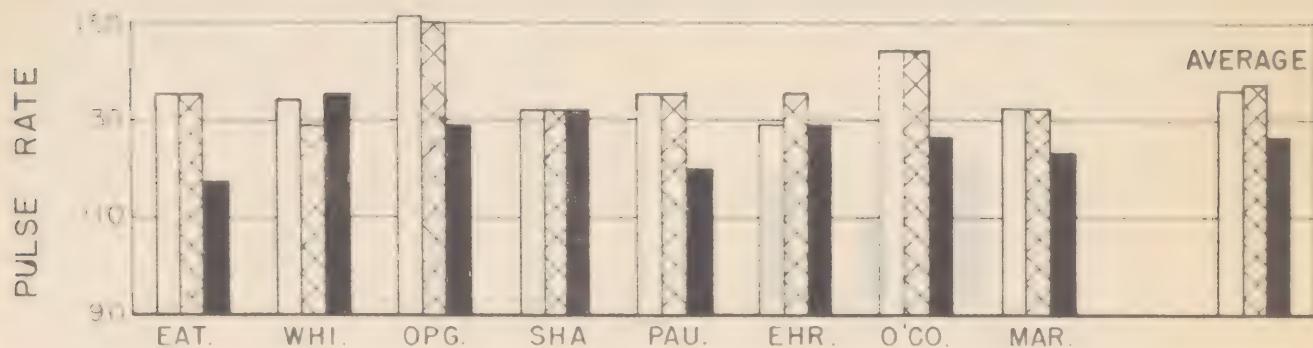
UNDER EXTREME HEAT CONDITIONS SOME MEN PREFERRED A  
BUT B WAS USUALLY USED. VISOR FOGS BADLY IF HUMIDITY  
IS HIGH

DRAWING 2



## CHART 2

### EFFECT OF AIR-COOLED SUIT ON MEN UNDER DESERT CONDITIONS



AIR TEMPERATURE 120 °F

RELATIVE HUMIDITY 20 %

SUIT AIR TEMPERATURE 70 °F

WORK RATE 4 M.P.H.

MEN - ACCLIMATIZED

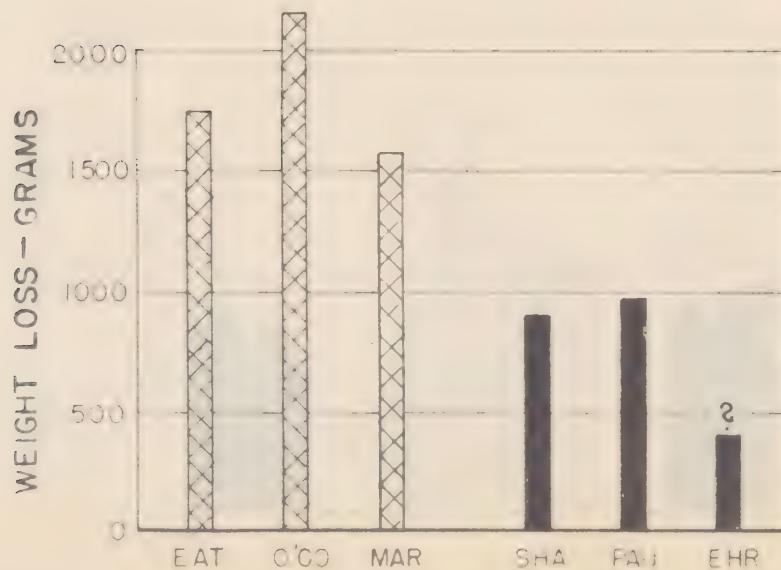
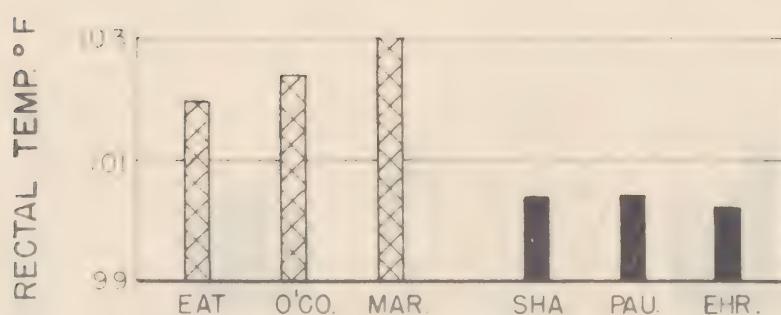
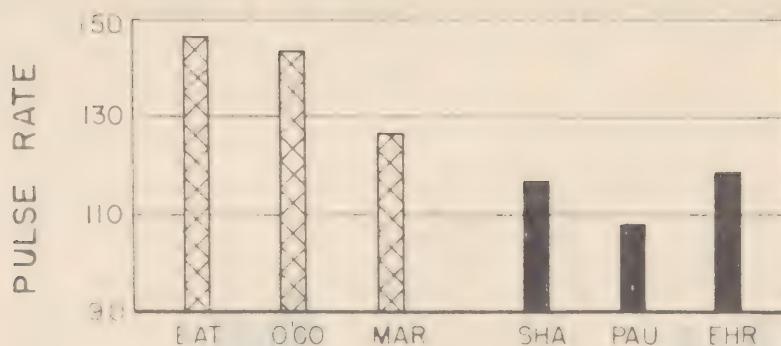
CONTROL  
NO SUIT  
WITH SUIT

## CHART 2



### CHART 3

#### EFFECT OF AIR-COOLED SUIT ON MEN UNDER EXTREME DESERT CONDITIONS



AIR TEMPERATURE 135 °F

RELATIVE HUMIDITY 11 - 15 %

SUIT AIR TEMPERATURE 70 °F

WORK RATE 3.25 M.P.H.

MEN - ACCLIMATIZED

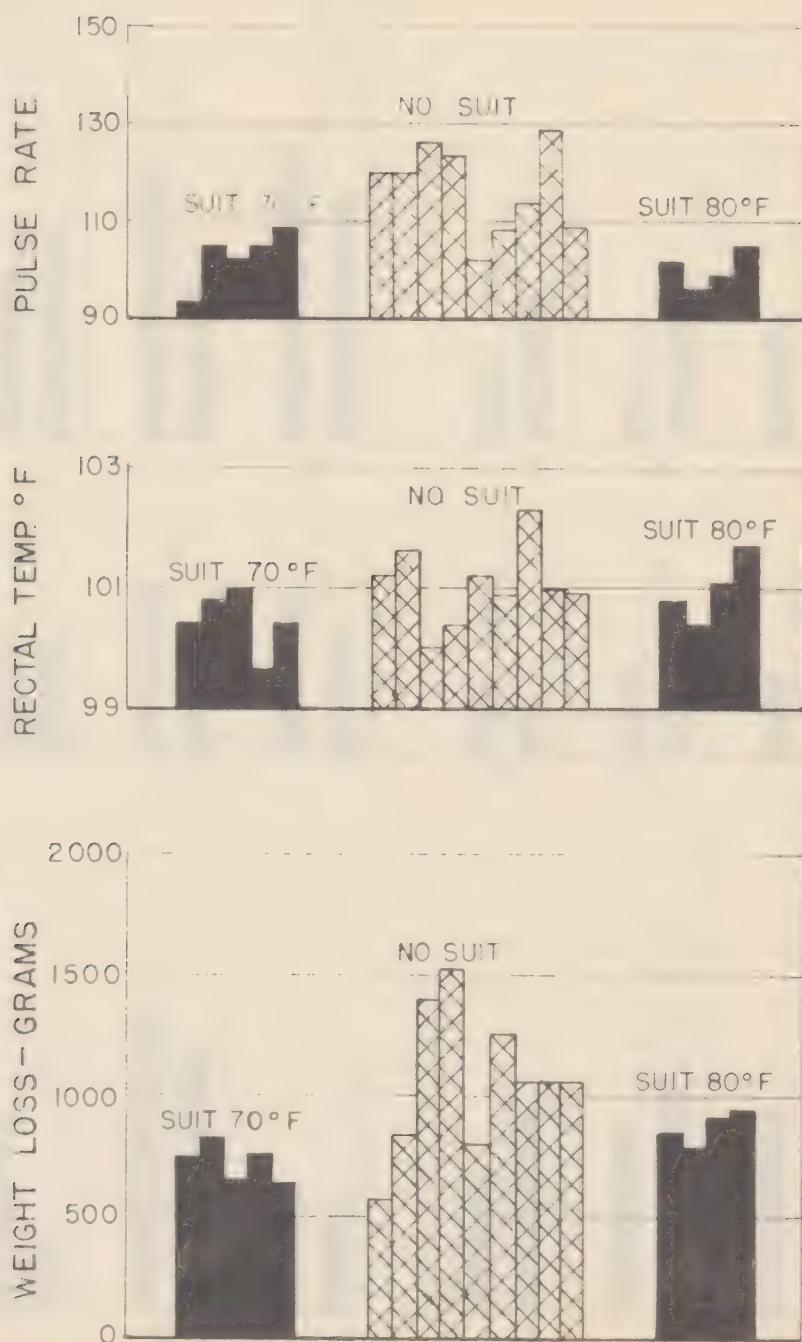
NO SUIT  
 WITH SUIT

### CHART 3



## CHART 4

### COMPARISON OF EFFICIENCY OF SUIT AT TWO SUIT-AIR TEMPERATURES



AIR TEMPERATURE 120°F

RELATIVE HUMIDITY 20%

WORK RATE 3.25 M.P.H.

MEN - ACCLIMATIZED

CHART 4

Incl. # 2



CHART 5

## EFFECT OF AIR-COOLED SUIT ON MEN UNDER JUNGLE CONDITIONS

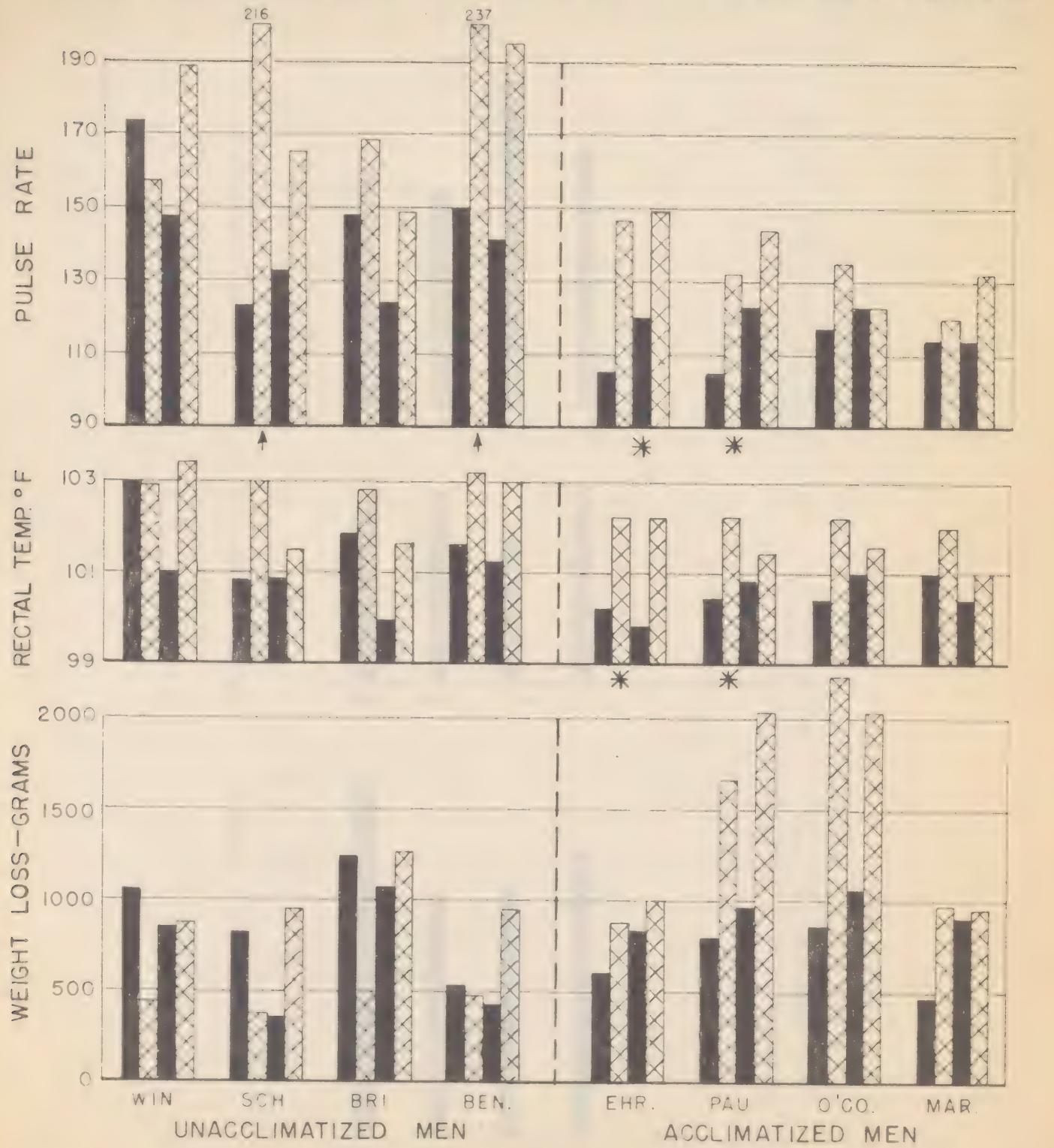


CHART 5

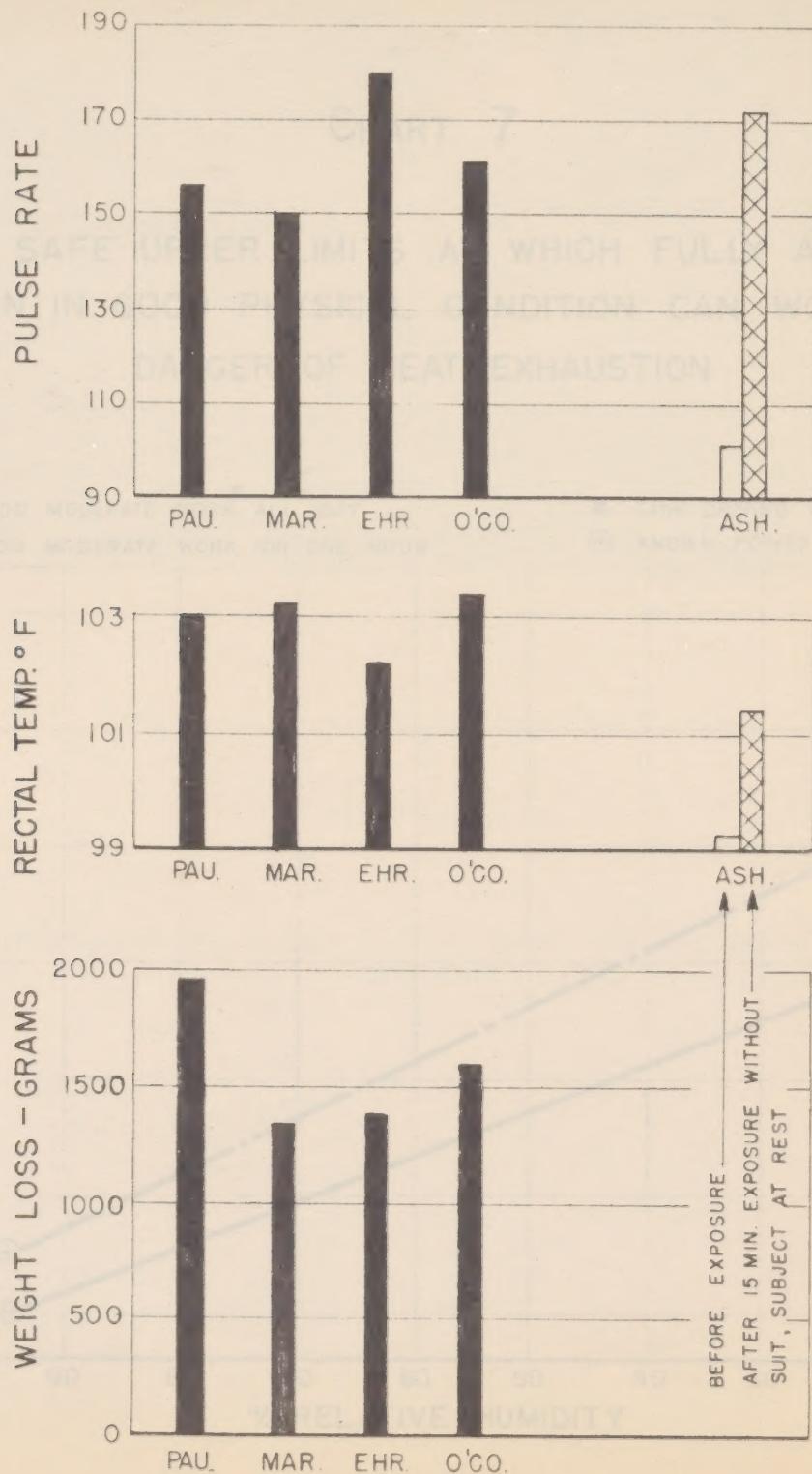
AIR TEMPERATURE 90°F  
RELATIVE HUMIDITY 96%  
SUIT AIR TEMPERATURE 75-80°F  
WORK RATE 3.25 MPH

↑ COULD NOT FINISH 1 HR. WALK  
\* TEMP 95°F, REL HUM 96%  
Without Suit  
With Suit



# CHART 6

## EFFECT OF AIR-COOLED SUIT ON MEN IN INTOLERABLE CLIMATE



AIR TEMPERATURE 110°F

RELATIVE HUMIDITY 90 %

SUIT AIR TEMPERATURE 70 °F

WORK RATE 3.25 M.P.H.

MEN - ACCLIMATIZED



## CHART 7

PROBABLE SAFE UPPER LIMITS AT WHICH FULLY ACCLIMATIZED  
YOUNG MEN IN GOOD PHYSICAL CONDITION CAN WORK WITHOUT  
DANGER OF HEAT EXHAUSTION

